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Ottawa Hull K1A 0C9

(21) (A1) 2,107,956
(22) 1993/10/07
(43) 1995/04/08

(51) INTL.CL.[5] G01N-011/04

(19)(CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Viscometer for Measuring a Single Sample Successively at a Plurality of Temperatures

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(57) 8 Claims

Notice: This application is as filed and may therefore contain an incomplete specification.

ABSTRACT OF THE DISCLOSURE

A viscometer is described for measuring a single sample successively at a plurality of temperatures. At least two tubular bodies are vertically spaced, such that a single sample of liquid flows by force of gravity between the tubular bodies. Each of the tubular bodies has a first end, a second end, and a flow channel extending between the first end and the second end. A heating coil is provided for heating liquid passing through the flow channel. A temperature sensor is provided for sensing a temperature of liquid passing through the flow channel. Two meniscus sensors are provided. A time sequence initiating meniscus sensor senses the passage of a meniscus of liquid within the flow channel. A time sequence terminating meniscus sensor is spaced a known axial distance along the flow channel from the first meniscus sensor, and senses the passage of the meniscus of liquid within the flow channel. The heating coils of the two tubular bodies are set for different temperatures. A back pressure relief vent is provided between the tubular bodies thereby preventing back pressure from adversely affecting the flow of liquid by force of gravity between the tubular bodies. A computer controller is connected to the meniscus sensors of each of the tubular bodies and a timer. As liquid flows successively through the tubular bodies the computer activates the timer when a first signal is received from the time initiating meniscus sensor indicating the passage of a meniscus of liquid. The computer stops the timer when a second signal is received from the time terminating meniscus sensor indicating the passage of the meniscus of liquid. The computer performs calculations of viscosity based upon the timed duration of flow over the known distance between the first signal and the second signal. The computer receives signals and performs calculations successively as the single sample of liquid successively passes through the tubular bodies.

The present invention relates to a viscometer for measuring a single sample successively at a plurality of temperatures.

BACKGROUND OF THE INVENTION

A viscometer measures viscosity of liquids; ie the resistance to flow of the liquids. One skilled in the art usually requires that the viscosity of a liquid be tested at two temperatures. Data taken at two temperatures can be interpolated in order to predict the behaviour of the liquid at all temperatures inbetween. The characteristics of the liquid as temperature changes is of critical importance in many applications, such as with lubricants.

In most cases in order to test a liquid at two temperatures, two separate samples must be presented to two different viscometer units, each operating at a different temperature. An example of this is British Patent Specification 1,399,783 filed by Mobil Oil Corporation and subsequently published in 1975. This reference discloses two individual viscometer units in parallel hookup, with both being controlled by a mini-computer. In accordance with the teaching of the reference two samples of the same liquid may be measured concurrently at two different temperatures. Presenting two samples to the equipment for each liquid tested doubles the labour and expense involved in preforming the tests.

The reference also contains an innovation permitting the same equipment to measure a single sample successively, first at 100 degrees Fahrenheit and then at 210 degrees Fahrenheit. To function automatically the reference teaches that a revolving turntable, pneumatic lift and adjustable framework system are required to manipulate the sample containers. Although the reference represents what was then an advance in the art, the number of samples that can be processed is restricted by the additional sample handling mechanisms

described and the time involved in manipulating sample containers.

SUMMARY OF THE INVENTION

What is required is a viscometer which can more efficiently measure a single sample successively at a plurality of temperatures.

According to the present invention there is provided a viscometer for measuring a single sample successively at a plurality of temperatures which includes at least two tubular bodies vertically spaced, such that a single sample of liquid flows by force of gravity between the tubular bodies. Each of the tubular bodies has a first end, a second end, and a flow channel extending between the first end and the second end. Means is provided for heating liquid passing through the flow channel. Temperature sensing means is provided for sensing a temperature of liquid passing through the flow channel. A time sequence initiating meniscus sensor is provided whereby the passage of a meniscus of liquid within the flow channel is sensed. A time sequence terminating meniscus sensor is spaced a known axial distance along the flow channel from the first meniscus sensor, whereby the passage of the meniscus of liquid within the flow channel is sensed. The heating means of the at least two tubular bodies are set for different temperatures. Back pressure relief means is provided between the tubular bodies thereby preventing back pressure from adversely affecting the flow of liquid by force of gravity between the tubular bodies. A computer controller is connected to the meniscus sensors of each of the tubular bodies and a timer. As liquid flows successively through the tubular bodies the computer activates the timer when a first signal is received from the time initiating meniscus sensor indicating the passage of a meniscus of liquid. The computer stops the timer when a second signal is received from the time terminating meniscus

sensor indicating the passage of the meniscus of liquid. The computer performs calculations of viscosity based upon the timed duration of flow over the known distance between the first signal and the second signal. The computer receives signals and performing calculations successively as the single sample of liquid successively passes through the at least two tubular bodies.

The minimum standard for viscosity testing is to perform measurement at two temperatures. With the viscometer, as described, testing of a single sample is conveniently and comparatively rapidly performed successively at two or more temperatures. The backpressure relief means in its most elementary form can consist of a spacing between the second end of the first tubular body and first end of the second tubular body to expose the liquid to atmospheric pressure.

Although beneficial results may be obtained through the use of the viscometer, as described, it is preferable to have a plurality of tubular members, each with a first tubular body and a second tubular body, whereby multiple samples are tested simultaneously. It has been found to be convenient to group these bodies into a bank consisting of several tubular members in a row. A bank consisting of eight tubular members has proven to be a manageable number. Such a bank can be run under the control of a single computer.

Although beneficial results may be obtained through the use of the viscometer, as described, valuable time can be lost in cleaning the viscometer if some automated cleaning system is not arranged. Even more beneficial results may, therefore, be obtained when the viscometer has a seal disposed between the second end of the first tubular body and the first end of the second tubular body such that cleaning fluids and air may be pumped under pressure through the first tubular body into the second tubular body.

Once the teachings of the present invention are understood the viscometer can be configured so that each of the tubular members has more than two tubular bodies. An additional tubular body can be added for each additional temperature at which it is intended the sample be tested. This permits viscosity readings to be obtained from a single sample successively at more than two temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings, wherein:

FIGURE 1 is a side elevation view of a viscometer constructed in accordance with the teachings of the present invention.

FIGURE 2 is a side elevation view of a plurality of the viscometers illustrated in **FIGURE 1**, arranged in a row for parallel processing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment, a viscometer for measuring a single sample successively at a plurality of temperatures generally identified by reference numeral 10, will now be described with reference to **FIGURES 1** and **2**.

Referring to **FIGURE 2**, viscometer 10 includes a row of tubular members 14. It has been found convenient to arrange tubular members 14 in rows of eight, and in the preferred embodiment eight tubular members 14 are illustrated. Referring to **FIGURE 1**, each of tubular members 14 are divided into a plurality of tubular bodies arranged in end to end relation, the number of which are dependent upon the number of temperatures at which a single sample processed through one of

tubular members 14 is to be measured. The embodiment illustrated in **FIGURE 1** is adapted for measurement at two temperatures and there is, therefore, two tubular bodies; a first tubular body 16 and a second tubular body 18. First tubular body 16 has a substantially vertical axis 20, a first end 22, a second end 24, and a first axial flow channel 26 extending between first end 22 and second end 24. A first orifice 27 is disposed in first axial flow channel 26. A first solenoid valve 28 is positioned adjacent second end 24 of first tubular body 16. First solenoid valve 28 is adapted to control the flow of liquids through first axial flow channel 26. A first means is provided for heating first tubular body 16. The first heating means is in the form of a first heating coil 30. A first temperature sensor is provided for sensing the temperature of liquid within first tubular body 16. The first temperature sensor is in the form of a first solid state temperature transducer 32, which works in concert with a computer controller as will hereinafter be further described. A first time sequence initiating meniscus sensor 34 is provided whereby upon opening of first solenoid valve 28 the passage of a meniscus of liquid 36 within first axial flow channel 26 is sensed. A first time sequence terminating meniscus sensor 38 is spaced a known axial distance along first axial flow channel 26 from first time sequence initiating meniscus sensor 34, whereby the passage of meniscus of liquid 36 is sensed.

Second tubular body 18 has a substantially vertical axis 40, a first end 42, a second end 44, and a second axial flow channel 46 extending between first end 42 and second end 44. A second orifice 47 is disposed in second axial flow channel 46. Axis 40 of second tubular body 18 is aligned with or intersects axis 20 of first tubular body 16 such that a single sample of liquid passes from first tubular body 16 to second tubular body 18 by gravity flow without human or mechanical intervention. Preferably, axis 40 of second tubular body 18 is coaxial with axis 20 of first tubular body 16. A second solenoid valve 48 is positioned adjacent second end 44 of

second tubular body 18. Second solenoid valve 48 is adapted to control the flow of liquids through second axial flow channel 46. A second means for heating second tubular body 18 is provided. Second heating means is in the form of a second heating coil 50. A second temperature sensor is provided for sensing the temperature of liquid within second tubular body 18. The second temperature sensor is in the form of a second solid state temperature transducer 52, which works in concert with a computer controller as will hereinafter be further described. A second time sequence initiating meniscus sensor 54 is provided, whereby upon opening of second solenoid valve 48 the passage of meniscus of liquid 36 within second axial flow channel 46 is sensed. A second time sequence terminating meniscus sensor 56 is spaced a known axial distance along second axial flow channel 46 from second time sequence initiating meniscus sensor 54, whereby the passage of meniscus of liquid 36 is sensed. Timing means is provided for timing the time between signals from meniscus sensors 34, 38, 54, and 56. The timing means consists of a timer 58 which is part of a greater computer control system as will hereinafter be described. A computer controller 60 is connected by conduit 61 to the described components on each of tubular members 14 and controls solenoid valves 28 and 48, heating coils 30 and 50; as well as monitoring temperature transducers 32 and 52, meniscus sensors 34, 38, 54, 56 and timer 58; and performing calculations of viscosity as will hereinafter be further described in relation to use and operation of viscometer 10.

Back pressure relief means is provided between first tubular body 16 and second tubular body 18 thereby preventing back pressure from adversely effecting the gravity flow of liquids from first tubular body 16 to second tubular body 18. The back pressure relief means includes a vent 62 on each of tubular members 14 connected to a common venting conduit 64 which is vented to atmosphere. Venting conduit 64 has a valve 66 whereby the venting conduit is closed during cleaning. A seal 68 is disposed between second end 24 of first tubular body

16 and first end 42 of second tubular body 18 of each of tubular members 14 such that cleaning fluids may be pumped under pressure through both first tubular body 16 and second tubular body 18 of tubular members 14. A drain manifold 70 is connected to 44 second end of second tubular bodies 18 of each of tubular members 14. Drain manifold 70 has a solenoid valve 72 which controls the flow of liquids through whereby drain manifold 70. Venting conduit 64 is connected into drain manifold 70 by branch conduit 73.

Some additional equipment is connected to viscometer 10 solely for the purpose of cleaning between testing. This equipment includes a compressed air source 74, an air control valve 76, a pressurized source of cleaning solution 78, a cleaning solution control valve 80, cleaning conduit 82 with a plurality of branch conduits 84, and cleaning caps 86 at the ends of each of branch conduits 84.

The use and operation of viscometer 10 will now be described with reference to **FIGURES** 1 and 2. A single sample to be tested is placed into first end 22 of first tubular body 16 of each of tubular members 14. First solenoid valve 28 is in a closed position blocking sample flow through first axial flow channel 26. Computer controller 60 activates first heating coil 30 to heat the liquid in first axial flow channel 26 to the first testing temperature for the sample. Data received from first temperature transducer 32 is monitored by computer controller 60 until a first testing temperature has been reached and maintained. Computer controller 60 then opens first solenoid valve 28 to permit liquid to flow by force of gravity from first end 22 of first tubular body 16 along first axial flow channel 26 through first orifice 27 to second end 24. First time sequence initiating meniscus sensor 34 is monitored by computer controller 60, and provides a signal to computer controller 60 when meniscus of liquid 36 passes. First time sequence terminating meniscus sensor 38 is similarly monitored by computer controller 60, and provides a signal to

computer controller 60 when meniscus of liquid 36 passes. Timer 58 is used to monitor the time it takes for meniscus of liquid 36 to pass first time sequence initiating meniscus sensor 34 and first time sequence terminating meniscus sensor 38. Computer controller 60 then performs calculations as to viscosity of the sample at the first temperature based upon the data collected as to the timed duration of the flow between first time sequence initiating meniscus sensor 34 and first time sequence terminating meniscus sensor 38. The liquid which passes from second end 24 of first tubular body 16 enters into first end 42 of second tubular body 18. Second solenoid valve 48 is in a closed position blocking sample flow through second axial flow channel 46. Computer controller 60 activates second heating coil 50 to heat the liquid in second axial flow channel 46 to the second testing temperature for the sample. Data received from second temperature transducer 52 is monitored by computer controller 60 until a second testing temperature has been reached and maintained. Computer controller 60 then opens second solenoid valve 48 to permit liquid to flow by force of gravity from first end 42 of second tubular body 18 along second axial flow channel 46 through second orifice 47 to second end 44. Second time sequence initiating meniscus sensor 54 is monitored by computer controller 60, and provides a signal to computer controller 60 when meniscus of liquid 36 passes. Second time sequence terminating meniscus sensor 56 is similarly monitored by computer controller 60, and provides a signal to computer controller 60 when meniscus of liquid 36 passes. Timer 58 is used to monitor the time it takes for meniscus of liquid 36 to pass second time sequence initiating meniscus sensor 54 and second time sequence terminating meniscus sensor 56. Computer controller 60 then performs calculations as to viscosity of the sample at the second temperature based upon the data collected as to the timed duration of the flow between second time sequence initiating meniscus sensor 54 and second time sequence terminating meniscus sensor 56. The liquid which passes from second end

44 of second tubular body 18 enters into drain manifold 70 where flows to a waste tank (not shown).

It should be noted that backpressure could interfere with gravity flow and likely would distort the readings in the absence of vents 62 on each of tubular members 14. Vents 62 are all vented to atmosphere through common venting conduit 64 controlled by solenoid valve 66. Solenoid valve 66 is normally closed, but is energized prior to a viscosity measurement being taken to allow the free gravity flow of liquid.

Viscometer 10 should be cleaned before testing a new series of samples. In order to clean viscometer 10, cleaning caps 86 are positioned at first ends 22 of first tubular bodies 16 of each of tubular members 14. With cleaning caps 86 in position a direct link is provide to the interior of viscometer 10 for the flow of either cleaning solution from cleaning solution source 78 or compressed air from compressed air source 74 through cleaning conduit 82 and branch conduits 84. Cleaning solution control valve 80 is then opened to enable cleaning solution to flow from cleaning solution source 78 through viscometer 10. First solenoid valve 28 and second solenoid valve 48 are maintained in an open position during cleaning. Solenoid valve 66 which controls backpressure venting is maintained in a closed position during cleaning. Solenoid valve 72 on drainage manifold 70 is maintained in an open position to carry cleaning solution to a waste tank. Cleaning solution control valve 80 is then closed to cut off the flow of cleaning solution, and air control valve 76 is opened to allow compressed air from compressed air source 74 to "blow" viscometer 10 clear of cleaning solution.

It will be apparent to one skilled in the art that modifications may be made to the illustrated embodiment without departing from the spirit and scope of the invention as defined by the claims. Although it is preferred that the tubular bodies be vertically aligned to enhance gravity flow, the

tubular bodies can be have serpentine flow channels as long as the basic requirement of flow from one tubular body to an underlying tubular body is maintained. There are a number of alternative ways to heat liquid passing through the flow channels. Valves are only necessary when the samples being taken are relatively large. If the samples merely consist of a few drops, valves become redundant. There are a number of alternative types of temperature sensors and meniscus sensors that can be used and several alternatives relating to placement of the same.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A viscometer for measuring a single sample successively at a plurality of temperatures, comprising:

a. at least two tubular bodies vertically spaced, such that a single sample of liquid flows by force of gravity between the tubular bodies, each of the tubular bodies having:

i. a first end, a second end, and a flow channel extending between the first end and the second end;

ii. means for heating liquid passing through the flow channel;

iii. temperature sensing means for sensing a temperature of liquid passing through the flow channel;

iv. a time sequence initiating meniscus sensor whereby the passage of a meniscus of liquid within the flow channel is sensed;

v. a time sequence terminating meniscus sensor spaced a known axial distance along the flow channel from the first meniscus sensor, whereby the passage of the meniscus of liquid within the flow channel is sensed;

b. the heating means of the at least two tubular bodies being set for different temperatures;

c. back pressure relief means being provided between the tubular bodies thereby preventing back pressure from adversely affecting the flow of liquid by force of gravity between the tubular bodies; and

d. a computer controller connected to the meniscus sensors of each of the tubular bodies and a timer, as liquid flows successively through the tubular bodies the computer activating the timer when a first signal is received from the time initiating meniscus sensor indicating the passage of a meniscus of liquid, the computer stopping the timer when a second signal is received from the time terminating meniscus sensor indicating the passage of the meniscus of liquid, the computer performing calculations of viscosity based upon the timed duration of flow over the known distance between the

first signal and the second signal, the computer receiving signals and performing calculations successively as the single sample of liquid successively passes through the at least two tubular bodies.

2. The viscometer as defined in Claim 1, wherein a valve is disposed in the flow channel whereby the flow of liquids through the flow channel is controlled.

3. A viscometer for measuring a single sample successively at a plurality of temperatures, comprising:

a. a plurality of tubular bodies in end to end relation, such that liquid flows between the tubular bodies, each of the tubular bodies having:

i. a substantially vertical axis, a first end, a second end, and an axial flow channel extending between the first end and the second end;

ii. a valve disposed in the axial flow channel adapted to control the flow of liquids through the axial flow channel;

iii. means for heating liquids passing through the axial flow channel;

iv. a temperature sensor for sensing the temperature of liquid passing through the axial flow channel;

v. a time initiating meniscus sensor such that upon opening of the valve the passage of a meniscus of liquid within the axial flow channel is sensed;

vi. a time terminating meniscus sensor spaced a known axial distance along the axial flow channel from the upper meniscus sensor, whereby the passage of the meniscus of liquid within the axial flow channel is sensed;

b. the heating means of the tubular bodies being set for different temperatures;

c. a computer controller including a timer, the computer controller being connected to the heating means, the temperature sensor, the meniscus sensors, and the valve of each of the tubular bodies, the computer controller controlling the flow of liquid through successive tubular bodies, the valve is maintained in a closed position blocking the flow of a sample of liquid to be tested, the heating means is activated to heat the sample until data from the temperature sensor indicates that a predetermined testing temperature has been reached, the valve is opened to permit liquid to flow by force of gravity from the first end of the tubular body through the second end of the tubular body, a first signal is received when a meniscus

of liquid passes the time initiating meniscus sensor, a second signal is received when the meniscus of liquid passes the time terminating meniscus sensor, the computer performing calculations of viscosity based upon the timed duration of flow over the known axial distance between the first signal and the second signal, the computer receiving signals and performing calculations successively as the single sample of liquid successively passes through the tubular bodies; and

d. back pressure relief means being provided between the tubular bodies thereby preventing back pressure from adversely effecting the flow of liquid by force of gravity between the tubular bodies.

4. A viscometer for measuring a single sample successively at two temperatures, comprising:

a. a first tubular body with a substantially vertical axis, a first end, a second end, and a first axial flow channel extending between the first end and the second end;

b. a first valve disposed in the axial flow channel adapted to control the flow of liquids through the first axial flow channel;

c. a first means for heating liquid passing through the first axial flow channel;

d. a first temperature sensor for sensing the temperature of liquid passing through the first axial flow channel;

e. a first time initiating meniscus sensor whereby upon opening of the first valve the passage of a meniscus of liquid within the first axial flow channel is sensed;

f. a first time terminating meniscus sensor spaced a known axial distance along the first axial flow channel from the first time initiating meniscus sensor, whereby the passage of the meniscus of liquid along the first axial flow channel is sensed;

g. a second tubular body with a substantially vertical axis, a first end, a second end, and a second axial flow channel extending between the first end and the second end, the first tubular body and the second tubular body being substantially in end to end relation with the axis of the second tubular body aligned with the axis of the first tubular body such that a single sample of liquid passes from the first tubular body to the second tubular body;

h. a second valve disposed in the second axial flow channel adapted to control the flow of liquids through the second axial flow channel;

i. a second means for heating liquids passing through the second axial flow channel;

j. a second temperature sensor for sensing the temperature of liquid within the second axial flow channel;

k. a second time initiating meniscus sensor whereby upon opening of the second valve the passage of a meniscus of liquid within the second axial flow channel is sensed;

l. a second time terminating meniscus sensor spaced a known axial distance along the second axial flow channel from the second time initiating meniscus sensor, whereby the passage of the meniscus of liquid along the second axial flow channel is sensed;

m. a computer controller including a timer, the computer controller being connected to the heating means, the temperature sensors, the meniscus sensors, and the valves of each of the tubular bodies, the computer controller controlling the flow of liquid through successive tubular bodies such that the first valve is maintained in a closed position blocking the flow of a sample of liquid to be tested, the first heating means is activated to heat the sample until data from the first temperature sensor indicates that a first testing temperature has been reached, the first valve is opened to permit liquid to flow by force of gravity from the first end of the first tubular body through the second end into the first end of the second tubular body, a first signal being received when a meniscus of liquid passes the first time initiating meniscus sensor, a second signal being received when the meniscus of liquid passes the first time terminating meniscus sensor, the computer performing calculations as to viscosity based upon the timed duration of flow between the first signal and the second signal, and sequentially the second valve is maintained in a closed position blocking the flow of a sample of liquid to be tested, the second heating means is activated to heat the sample until data from the second temperature sensor indicates that a second testing temperature has been reached, the second valve is opened to permit liquid to flow by force of gravity from the first end of the second tubular body through the second end, a first signal being received when a meniscus of liquid passes the second time initiating meniscus sensor, a second signal being received when the meniscus of liquid passes the second time terminating meniscus sensor, the computer

performing calculations as to viscosity based upon the time duration of flow between the first signal and the second signal, the computer receiving and performing calculations successively as the single sample of liquid successively passes through the first tubular body and the second tubular body; and

n. back pressure relief means being provided between the first tubular body and the second tubular body thereby preventing back pressure from adversely affecting the flow of liquid by force of gravity between the first tubular body and the second tubular body.

5. The viscometer as defined in Claim 4, wherein a plurality of first tubular bodies and second tubular bodies are arranged to form a bank, whereby multiple samples are tested simultaneously.

6. The viscometer as defined in Claim 4, the back pressure relief means being a vent to atmosphere.

7. The viscometer as defined in Claim 4, having a seal disposed between the second end of the first tubular body and the first end of the second tubular body such that cleaning fluids and air may be pumped under pressure through the first tubular body into the second tubular body.

8. A viscometer for measuring a single sample successively at two temperatures, comprising:

a. a bank of tubular members, each tubular member having a first tubular body and a second tubular body;

b. the first tubular body having a substantially vertical axis, a first end, a second end, and a first axial flow channel extending between the first end and the second end;

c. the second tubular body having a substantially vertical axis, a first end, a second end, and a second axial flow channel extending between the first end and the second end, the first tubular body and the second tubular body being substantially in end to end relation with the axis of the second tubular body aligned with the axis of the first tubular body such that a single sample of liquid passes from the first tubular body to the second tubular body;

d. a first solenoid valve disposed in the first axial flow channel adapted to control the flow of liquids through the first axial flow channel;

e. a first heating coil disposed in the first axial flow channel, whereby liquid passing through the first axial flow channel is heated;

f. a first temperature sensor for sensing the temperature of liquid passing through the first axial flow channel;

g. a first time initiating meniscus sensor whereby upon opening of the first valve the passage of a meniscus of liquid within the first axial flow channel is sensed;

h. a first time terminating meniscus sensor spaced a known axial distance along the first axial flow channel from the first time initiating meniscus sensor, whereby the passage of the meniscus of liquid along the first axial flow channel is sensed;

i. a second solenoid valve disposed in the second axial flow channel adapted to control the flow of liquids through the second axial flow channel;

j. a second heating coil disposed in the second axial flow channel,.whereby liquids passing through the second axial flow channel are heated;

k. a second temperature sensor for sensing the temperature of liquid within the second axial flow channel;

l. a second time initiating meniscus sensor whereby upon opening of the second valve the passage of a meniscus of liquid within the second axial flow channel is sensed;

m. a second time terminating meniscus sensor spaced a known axial distance along the second axial flow channel from the second time initiating meniscus sensor, whereby the passage of the meniscus of liquid along the second axial flow channel is sensed;

n. a computer controller including a timer, the computer controller being connected to the heating means, the temperature sensors, the meniscus sensors, and the valves of each of the tubular bodies, the computer controller controlling the flow of liquid through successive tubular bodies such that the first valve is maintained in a closed position blocking the flow of a sample of liquid to be tested, the first heating means is activated to heat the sample until data from the first temperature sensor indicates that a first testing temperature has been reached, the first valve is opened to permit liquid to flow by force of gravity from the first end of the first tubular body through the second end into the first end of the second tubular body, a first signal being received when a meniscus of liquid passes the first time initiating meniscus sensor, a second signal being received when the meniscus of liquid passes the first time terminating meniscus sensor, the computer performing calculations as to viscosity based upon the timed duration of flow between the first signal and the second signal, and sequentially the second valve is maintained in a closed position blocking the flow of a sample of liquid to be tested, the second heating means is activated to heat the sample until data from the second temperature sensor indicates that a second testing temperature has been reached, the second valve is opened to permit liquid to flow by force of gravity

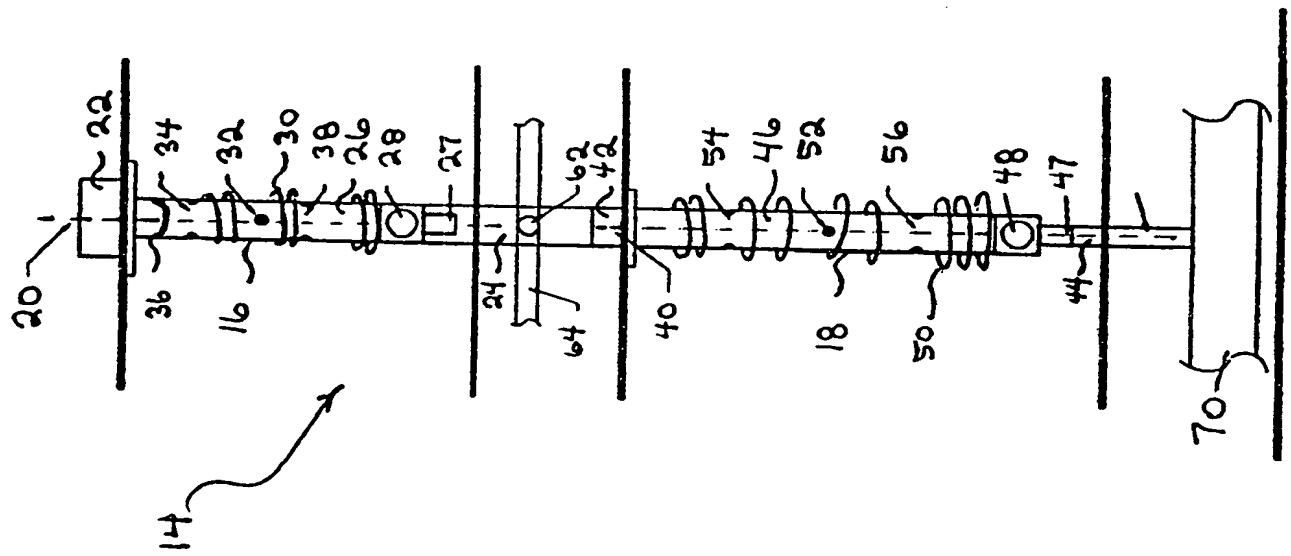
from the first end of the second tubular body through the second end, a first signal being received when a meniscus of liquid passes the second time initiating meniscus sensor, a second signal being received when the meniscus of liquid passes the second time terminating meniscus sensor, the computer performing calculations as to viscosity based upon the time duration of flow between the first signal and the second signal, the computer receiving and performing calculations successively as the single sample of liquid successively passes through the first tubular body and the second tubular body; and

o. back pressure relief vents between the first tubular body and the second tubular body of each tubular member in the bank thereby preventing back pressure from adversely affecting the flow of liquid by force of gravity between the first tubular body and the second tubular body, the back pressure relief vents of all tubular members of the bank being connected to a common venting conduit vented to atmosphere, the venting conduit having a solenoid valve;

p. a seal disposed between the second end of the first tubular body and the first end of the second tubular body of each tubular member such that cleaning fluids may be pumped under pressure through the first tubular body into the second tubular body; and

q. a drain manifold connected to the second end of the second tubular bodies of each of the tubular members in the bank, the drain manifold having a solenoid valve.

FIG 1



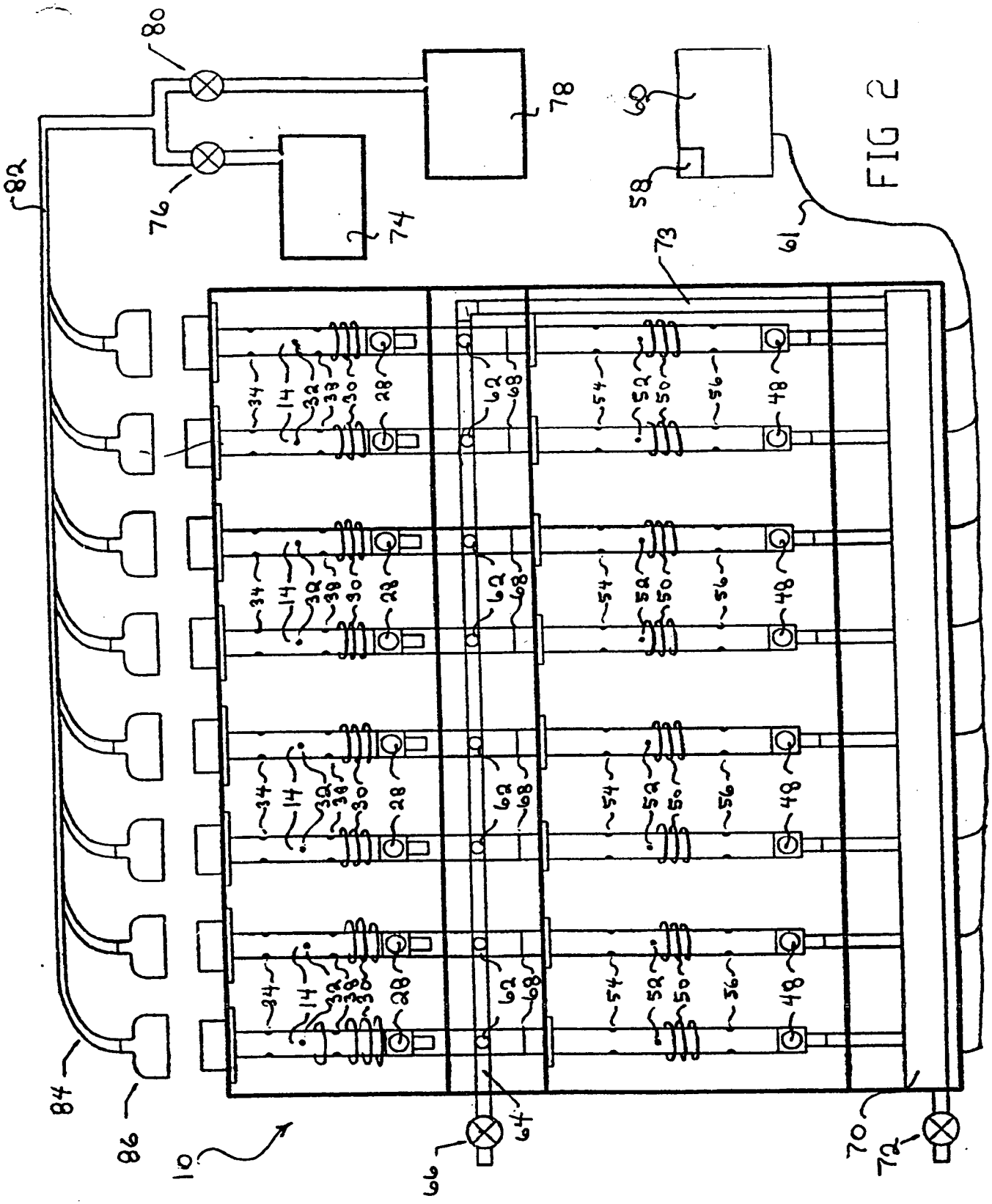


FIG 2

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